

Response to Peer Review Comments

Chapter 6: Environmental Chemistry

Peer Reviewer: Paul Brant-Rauf

No pertinent comments on Chapter 6.

Peer Reviewer: Gregory Turk

No pertinent comments on Chapter 6.

Peer Reviewer: Gary Ginsberg

No pertinent comments on Chapter 6.

Peer Reviewer: Gregory Turk

No pertinent comments on Chapter 6.

Peer Reviewer: Herman Gibb

No comments presented for Chapter 6.

Peer Reviewer: Chunming Su

● *This is a well-written report that outlines the review of New Jersey Chromium Workgroup on the application of the current chromium standards and proposed revision of the current standards. All four subgroups (Risk Assessment, Analytical Chemistry, Air and Dust Transport, and Chromium Environmental Chemistry) have done an excellent job in summarizing our current knowledge on chromium ore processing residue issues. Their suggestions appear to be scientifically sound. Technically, the report is in good shape. There are some editorial points that can be looked at in order to further improve the report.*

No response.

Peer Reviewer: Ken Stollenwerk

● *I found the report to be very thorough. Therefore, I did not have a lot of comments. Overall, I agree with the conclusions and recommendations presented in this report. I realize that some of the recommendations may go beyond the original charges made to the working group, particularly in the Chromium Environmental Chemistry Subgroup. However, I believe that the additional proposed research is necessary to address the questions relating to chromium behavior in these complex environments.*

No response.

● *Determination of the fate and transport of chromium at COPR sites is particularly difficult because of the potential for changes in the oxidation/reduction state of chromium, and the dependency of Cr(VI) transport on physical and geochemical factors that can vary widely from site to site and within any given site. Therefore, defining generic cleanup standards for COPR is difficult.*

Response: We agree with reviewer's comment. The issue of oxidation/reduction and interconversion in the environment is significant and complex. Furthermore,

the Department is no longer proposing a generic impact-to-groundwater cleanup standard for either COPR waste material or chromium-contaminated soil.

- *An important consideration is the rate of oxidation of Cr(III) to Cr(VI) in COPR contaminated soils. The Cr(VI) formed could then leach deeper into the subsurface, eventually reaching groundwater. The potential for Cr(III) oxidation should be better quantified in order to help determine COPR cleanup standards.*

Response: We agree with the reviewer's comment. This comment is consistent with the information that is presented in the report; that is, the potential for Cr(III) oxidation needs quantification in order to better address this issue in future clean-up standards. As information on this phenomenon becomes available, the clean-up standards will be revised, accordingly. However, given the relatively slow rate of chromium interconversion, the topic is difficult to study under laboratory conditions.

- *If not already in place, a procedure for evaluating COPR sites with respect to transport of Cr(VI) in the subsurface should be developed. Important considerations are site hydrology and geochemistry.*

Response: Understanding specific site hydrology and geochemistry is very complicated to evaluate in a predictive manner. We agree with the reviewer's suggestion and seek to address this issue through research. As information on this phenomenon becomes available, the clean-up standards will be revised, accordingly. We agree that our groundwater staff should continue to evaluate the transport of chromium in groundwater at these sites and provide more detailed documentation in the reports issued for COPR sites. Regarding the potential for chromium transport in the soil vadose zone or in COPR waste material, the SPLP test discussed in the document is the most practical tool for this assessment. Regarding the suggestion for more advanced geochemical assessment procedure, our current understanding of chromium geochemistry at these COPR sites is inadequate to develop such a procedure. Such an assessment would likely require detailed site-specific research.

- *Specific comments:*

Ch. 6, p. 95: A distinction between COPR waste material and COPR-waste contaminated soils would be justifiable from a geochemical viewpoint. High concentrations of COPR waste in a soil would result in elevated pH values and a difference in the behavior of Cr. For example, Cr(VI) would be less likely to adsorb. In mixtures where COPR concentrations are relatively low, the buffering capacity of the soil would maintain pH values near that of the soil and the adsorption behavior of Cr(VI) would be different. As mentioned, there are other parameters that could be used to make the distinction. However, I would expect many of the COPR-soil mixtures to fall somewhere in between, making clear-cut distinctions difficult. Perhaps a third category such as moderately contaminated soils would be appropriate.

Response: We will address reviewer's comment by adding clarifying language in the sections where the discussion focuses on distinguishing between COPR waste material and COPR-soil mixtures. Although identifying a third category seems

theoretically useful, the parameters for distinguishing among three (versus two) categories is not feasible at this time. Rather, we seek to distinguish between the waste material and waste/soil mixtures as two broad categories. As we proceed, we can determine whether it is feasible to add a third or more categories.

- *Ch. 6, p. 101: The K_d given here is for hexavalent Cr. Suggest labeling chromium as hexavalent Cr here and throughout the subsequent discussion that relates to adsorption.*

Response This section has been removed, because we are no longer proposing generic cleanup standards for chromium contamination. All numerical values for chromium K_d values have been removed from this discussion.

- *Ch. 6, p. 110: Should this be Cr(III) instead of Cr(VI)?*

Response: Yes. This was a typographical error.

Peer Reviewer: John Chorover

1. The Nature of COPR.

General Comments:

- *In the context of the charge to describe the “nature of COPR”, it would seem that the size of COPR particles, or more precisely, the specific surface area of the COPR particles, would be an important determinant in respect to the rate of Cr release at a given site. This is because the specific surface area determines the amount of reactive interface between solid and solution phases for a given mass of material. Thus, all other factors (mineralogy, pH, etc.) being equal, that COPR with higher specific surface area will be subjected to higher mass normalized rates of dissolution. In addition, the precise Cr-bearing mineralogy of the COPR would certainly be important to the rate of Cr(VI) release.*

Response: We agree with the commenter’s point that particle size, or surface area, is an important factor in defining COPR’s behavior in the environment. Knowing the mineralogy of the COPR is vital to understanding the mechanisms of dissolution, and the work group has identified the need to conduct mineralogical assessments on COPR samples collected from NJ sites.

- ***Specific Comments:***

P. 93 bottom through P. 94 top. I concur with the findings of the subgroup pertaining to the key processes that determine the fate and transport of Cr at COPR sites (dissolution of Cr-containing COPR materials, oxidation of Cr(III) to Cr(VI), reduction of Cr(VI) to Cr(III), adsorption-desorption of Cr species, and transport of Cr to groundwater). However, one process that should be added is the precipitation Cr containing solids, which is distinct from adsorption or accumulation at particle surfaces (e.g., reduction of Cr (VI) can result in solid phase incorporation of Cr(III), and the formation of Cr(VI) “blooms” apparently reflects precipitation of Cr salts). It is also true that modeling fate and transport of Cr in these systems is made difficult by an incomplete understanding of the relative kinetics of the processes in complex matrices.

Response: We agree with the comment that precipitation is an important fate and transport phenomenon. The language in the chapter has been changed to better emphasize that “concentration effect” includes precipitation.

- *P. 94, line 20: The statement that chromite ore contained “45 to 50 percent trivalent chromium” is unclear. Does this mean that roughly half the mass of the ore was Cr(III) or that half of the ore Cr was in the trivalent oxidation state?*

Response: The statement has been clarified to state that chromite ore generally contains 45 to 50% Cr(III) by mass. Chromite ore consists primarily of chromium (III), iron, aluminum and magnesium ions in an oxidic matrix. The chromite ore generally used in the manufacturing process contained between 45 to 50% chromic oxide (Cr₂O₃).

- *P. 95, line 21: It is important to be clear on distinguishing issues such as “solubility” from the “rate” of dissolution. At this point in the report, it is stated that pH exerts significant control over solubility of Cr(VI) from COPR, which implies that pH exerts a control over the concentration of Cr(VI) in equilibrium with the solid phase. My impression is that none of the Cr(VI)-bearing mineral phases are thermodynamically stable under the environmental conditions where they reside, since the dissolved Cr(VI) is consistently lost from the open system with continuing throughput of fresh water. Rather, it seems more likely that the effects of pH are to alter the rate at which the Cr(VI)-bearing minerals undergo dissolution.*

Response: We agree that a distinction should be made between “solubility” and “rate of dissolution.” The sentence at line 21 discusses only results from equilibrium modeling, which did not take kinetics into account. We have clarified the discussion, particularly with respect to modeling and experimental results.

- *P. 95: In respect to the distinction between COPR and COPR-soil mixtures, it would seem that, in addition to the factors listed, mineralogy could provide an important distinction between these two materials. Those minerals present in the COPR are not typically found in nature, so their dilution relative to native soil minerals could be used as a proxy for distinguishing COPR from its soil mixture.*

Response: We agree that mineralogy can be useful for this purpose and have added this as a possibility as appropriate in the chapter.

2. Transport to Groundwater.

• General Comments:

The studies by Geelhoed et al. (2002), Weng et al. (1994) and James (1994) show a fraction of the Cr that is “readily leached” from the COPR. However, none of the studies appear to address the long term effects of sequential leaching, weathering, drying, and re-leaching, as would be observed in the field. Dissolution may drive conversion of solid phase Cr to either more or less “labile” forms. The problem with the existing data is that the long-term transformation processes that control dissolution into groundwater over time scales of years, are not well represented by short term one-leach types of experiments. The solid phase speciation of Cr is key to the kinetics of Cr release (and this probably explains the poor correlations between total and eachable Cr reported by

NJDEP, 2004a), as is the change in solid phase speciation with time of COPR weathering in the field.

Response: We agree. Laboratory studies are unable to reproduce processes that occur over long periods of time. Field studies to monitor these processes are difficult to conduct and require long-term funding commitments.

Specific Comments:

- *P 96, line 8: What was the duration of the batch leaching tests? The length of time for solid solution equilibration is an important factor influencing the mass fraction of Cr released.*

Response: The tests were run for either 4 or 26 days. This has been added to the document.

- *P. 96, line 28: With regard to the statement that “these values are likely to be lower than field conditions because of the large volume of extractant employed”, it is worth remembering that it is not easy to compare batch extractions with field data because of the much greater mixing afforded in the former case. Comparative studies have shown that weathering kinetics are generally accelerated in batch lab systems relative to field-scale measurements because of the greater contact between solution and reactive interface of the solids. This is despite the fact that the concentration in solution may indeed be lower for batch systems because of the dilution effect.*

Response: We generally agree with the comment that the vigorous extraction conditions may partly cancel the effect of a large volume of extractant. However, we cannot speculate on this quantitatively and therefore have chosen not to modify the text here. Also, we feel the term “weathering kinetics” is best used for long term processes. We feel “dissolution kinetics” is a better term for batch experiments.

- *P 97, line 13: In addition to those characteristics listed, I would add that the solid phase speciation (i.e. the form or mineralogy) of the Cr is important.*

Response: We agree. Language to reflect this has been added.

- *P 98, line 1-22: It would seem that this discussion assumes that reducing agents are exhausted following transfer of electrons to the Cr(VI). Whereas this may be true in some cases, it is often observed that these reducing agents can be re-established by their own subsequent reduction (by other reducing agents). For example, Fe(III) reduction to Fe(II) is catalyzed by iron reducing microorganisms that utilize Fe(III) as a terminal electron acceptor in respiration when labile organic matter is present, but molecular oxygen is unavailable. If Fe(II) is a principal reducing agent for Cr(VI), it is likely that each mole of Fe(II) will undergo several oxidizing and reducing cycles such that it may be “renewed” as a reducing agent, so long as molecular oxygen is limiting and sufficient organic matter is available for microbial respiration. Thus, in suboxic systems, each mole of Fe(II) would be available to reduce as many moles of Cr(VI) as can be accomplished by subsequent oxidation-reduction cycles of the Fe. In other words, the reducing power of the Fe(II) can be regenerated.*

Response: The discussion in the chapter refers to the ultimate source of the reducing agent, namely the organic carbon (the meadow mat). The meadow mat is specified in the discussion. A short discussion of redox cycling has been added to the paragraph.

- *P. 98, line 29-on: The transport of even nitrate and chloride can be retarded relative to water transport if the porous medium exhibits a net positive charge due to enrichment of Fe and Al oxides or hydroxides. If chromate exhibits a higher affinity for positively charged surfaces than nitrate or chloride, its retardation will be enhanced.*

Response: While not necessarily as mobile as water itself, nitrate and chloride are known to be generally mobile in soils. Soils are generally negatively charged except at low pH. The language in this sentence has been revised to clarify that nitrate and chloride are generally transported readily through the soil. We do state that chromate is more readily retained by soil than nitrate and chloride.

- *P. 100-102: The use of soil-water partition coefficients (K_d values) to predict transport is problematic in cases where isotherm behavior is non-linear (e.g., Langmuir behavior), since in that case, the actual K_d will depend on the solution phase concentration. For example, if the isotherm follows the Langmuir shape, the K_d decreases with increasing aqueous phase concentration. Thus, in addition to exhibiting pH dependence (as indicated on p. 102) the K_d for Cr is dependent on aqueous phase Cr concentration. To complicate matters further, the pH and concentration dependence of the K_d will be strongly influenced by soil mineralogy. Soils containing high specific surface area of Fe and Al oxides tend to exhibit greater positive charge at a given pH, than those that have low interfacial areas of Fe and Al oxide. Thus, increasing amounts of Fe and Al solids are likely to enhance the K_d values, all else being equal.*

Response: We acknowledge these comments. However these complicating factors are not characterized well enough in the scientific literature to incorporate them into models for routine use. This is why USEPA has suggested the simple partitioning model for its soil screening guidance, which only requires the K_d (with pH adjustment as necessary). The discussion on pages 100-102 is simply presenting the USEPA approach.

- *Saturation of adsorption sites is certainly a potential issue, and could lead to breakthrough as suggested here. It is worth remembering, however, that site saturation is not required for breakthrough to occur. Rather, sorption-desorption equilibria simply serve to slow or “retard” migration of the contaminant plume relative to the solvent water.*

Response: We agree. Language to clarify has been added.

- *P 103, line 16: I think it would be better to state that “concentrations of the constituents in solution after dissolution are independent of the concentration of the mineral in the solid phase, so long as that mineral is still present at mineral solubility equilibrium.”*

Response: We agree. This change has been made.

- *P. 103: In the discussion of equilibrium solubility relationships, it must be kept in mind that this is a multi-component equilibrium. Thus if several solids are present, the concentration of Cr(VI) in solution at a metastable equilibrium will be that governed by the most soluble solid. The concentration can be reduced thereafter as Cr(VI) progressively precipitates into less soluble solids and the more soluble solids are transformed to these less soluble solids in the process known as “Ostwald ripening”.*

Response: We agree with the commenter. As with the simple partitioning equation, there are complicating factors that we feel are beyond the scope of this document, particularly since practical models are not available to account for these factors.

- *P. 104: It is stated that MINTEQA2 and related chemical speciation models may be “too advanced” for routine use. However, I would argue that this is not necessarily the case, and it would help to address the problem of multicomponent equilibria outlined just above, given that the person using the model was sufficiently trained (a few days for a chemist). The problem with these models on the other hand, is that they are only as good as the thermodynamic data they contain. Thus, it would be essential to confirm that sound thermo data are available for all species of interest. If the native database is insufficient, it can be modified. The other caveat is that these models assume achievement of equilibrium, which is often not the case in real field systems, as is indicated on p. 104.*

Response: The MINTEQA2 model is best suited for Ph.D. academic inorganic chemists. It is not practical for use at NJDEP without training (as the reviewer points out), and this would only be worthwhile if the model offered a clear benefit. As the reviewer points out, the lack of needed input data can be a problem with the model. It is a certainty that adequate thermodynamic data is not available for several of the species present at COPR waste sites (some of which have been only recently discovered). Furthermore, the various species in solution at COPR sites and their concentrations have not been adequately characterized. Finally, the reviewer mentions that field conditions are not likely to be at equilibrium as the MINTEQ model requires. Considering all these issues, model is judged to be impractical for use at COPR sites.

- *P 105-106: The written assessment of alternative remediation standards seems reasonable, as does the treatment of COPR material as a continuing source.*

Response: We agree.

- *P. 107: I am not convinced that material pH serves as an unambiguous proxy for source vs. soil material. I would imagine that COPR pH decreases with aging time even in the absence of soil. In this regard, the total Cr concentration criterion may be preferable. However, it would seem that quantitative mineralogical assessments would be least ambiguous, since solid phase Cr is present in unique mineral types. This approach would require a more intensive data acquisition for a given site/sample. I agree that research is needed in this area.*

Response: We agree. The methodology for distinguishing between COPR and COPR-soil mixtures has not yet been developed, though it is anticipated that

many factors in addition to pH will be used for this characterization. Mineralogical analysis would certainly be considered.

3. Interconversion

- *General Comments:*

This section emphasizes the role of various electron acceptors in promoting the oxidation of Cr(III) to Cr(VI). While the speciation and concentration of oxidizing agents is undoubtedly important, the speciation of Cr(III) is likely of equal importance. This review of the literature should specify which species of Cr(III) are being oxidized in each case cited. Were all studies conducted on aqueous phase Cr(III)? The kinetics of solid phase Cr(III) oxidation is likely highly variable depending on the form present in COPR.

Response: We agree. More specifics on the studies evaluated have been added.

- *At alkaline pH values characteristic of COPR (i.e., pH 10 and higher) the dominant aqueous species of Cr(III) are Cr(OH)₃ and Cr(OH)₄⁻. This is different than the speciation present at lower pH (conditions under which most of the cited studies have been conducted), a factor that is likely to impact oxidation rates.*

Response: We agree.

Specific Comments:

- *P. 110-112: This review of redox transformations of Cr suggests that systems containing significant Mn(IV) oxides have a greater tendency to oxidize Cr(III) whereas those systems comprising high concentrations of organic matter and Fe(III) oxides, have a greater tendency toward reduction of Cr(VI) (via Fe(II)-induced reduction). This seems consistent with the existing literature and so measures of these constituents in COPR sites might provide some utility for predicting interconversion. However, most of the cited research was conducted on model systems comprising Mn oxide or Fe oxide-humic suspensions. Further work is needed to verify the effects for COPR and COPR-soil mixtures.*

Response: We agree with the reviewer's comment that more work is needed. The recommendations include interconversion research. A sentence noting this has been added.

4. Concentration Effect

General Comments:

- *This portion of the review emphasizes adsorption as a function of particle size. However, the surface chemistry of the particles is a very important criterion for the production of surface excess. For example, HCrO₄⁻ and CrO₄²⁻ will not accumulate on negatively-charged surfaces, such as structurally-charged layer silicate clay minerals or silica, whereas it will accumulate on positively-charged surfaces such as Fe and Al oxides and hydroxides, particularly when low pH promotes an increase in positive surface charge through surface protonation reactions. Thus, it is important to consider, not only the size of particles, but also their mineralogical composition and, hence, charge properties, when considering adsorption of anionic chromate.*

Response: We agree with the reviewer and have expanded the discussion to include the points about mineralogy of the adsorbate.

Specific Comments:

• *P. 118, 3rd paragraph: This discussion deals with pH dependency of Cr(III) and Cr(VI) adsorption. To elucidate the mechanisms governing this dependency it would be worth including some discussion of the speciation of aqueous phase Cr(III) and Cr(VI) as a function of pH. This aqueous phase speciation is what controls the affinity of Cr for surfaces under various chemical conditions. For example, the distribution of Cr(VI) species is pH dependent, with a pKa value for HCrO_4^- of 6.5. Similarly, the solubility of the hydrous solid phase $\text{Cr}(\text{OH})_3$ exhibits strong pH dependence because of aqueous phase speciation changes. Whereas the cationic species $\text{Cr}(\text{OH})_2^+$ is predominant below pH 8, the neutral species $\text{Cr}(\text{OH})_3$ and anionic species $\text{Cr}(\text{OH})_4^-$ become increasingly prevalent at $\text{pH} > 9$. Thus, given the changing charge properties of the hydrolysis products for both Cr(VI) and Cr(III), we expect strong pH dependency of adsorption. Superimposed on this is the pH dependent charge properties of the Al and Fe oxides, which serve as important sorbents for hexavalent Cr. Much of the phenomenological description of pH dependency of “Cr(VI) solubility” can be understood in the context of acid-base chemistry of both the Cr species and the mineral surfaces.*

Response: We agree that a discussion of pH, speciation, and adsorption would be useful here. A short discussion has been added as a preamble to the cited paragraph.

Recommendations (p. 121-124):

1. *Nature of COPR. Based on the documentation included in the report, I agree with the need for research on the nature (particularly mineralogy) of COPR, for the reasons stated throughout this review.*

Response: We agree that the mineralogy is an important consideration. It has been added to the recommendation.

2. *Transport to Groundwater. Based on the documentation included in the report, I agree with the research needs listed.*

No Response.

3. *Interconversion. Based on the documentation included in the report, I agree with the research needs listed. Relations between adsorption and redox transformation may prove to be particularly important.*

No Response.

4. *Concentration Effect. Based on the documentation included in the report, I agree with the research needs listed. However, it seems that the most information will be obtained from the particle size concentration effect studies if Cr(VI) accumulations are correlated with both particle size and particle mineralogy/chemical composition. I am concerned that a focus solely on particle size will lead to equivocal results and*

relatively poor predictive power. Inclusion of data on solid phase composition across the particle size range should improve the predictive power significantly.

Response: An attempt will be made to include a mineralogical assessment of the material used in this research. However, it may be beyond the scope of the investigator's ability. This will depend in large part on the availability of the mineralogical techniques by the investigator. A request to incorporate mineralogical characterizations has been added to the research recommendation.

Other Specific Comments:

- The term "blooms" is used in several locations throughout the report, presumably to denote visible surficial accumulations of Cr(VI) salts. However, the term is never fully defined, and it is not until P. 110 or so that it becomes somewhat clear what is intended by this term. The term "blooms" should be defined precisely when it is first introduced, in terms of the precise chemical compositions or range of chemical compositions intended.*

Response: The term has been better and earlier defined.

Peer Reviewer: C.P. Huang

- Comment #1. Cr release equations. Equations (1) and (2) were used to predict the release of chromium into the groundwater from organic and inorganic contaminants, respectively. These equations were derived on a simple adsorption equilibrium senior. A chemical transformation term, i.e., redox reaction, may be incorporated. For example:*

$$IGWSRS = C_{gw} ((K_{oc}F_{oc} + (0_w + 0_a H')/p_b + k) * DAF, \text{ or organic contaminants and } IGWSRS = C_{gw} ((K_d + (0_w + 0_a H')/p_b + k) * DAF, \text{ or organic contaminants, where } k \text{ is the rate of chemical transformation such as reduction or oxidation reaction.}$$

Response: The simple partitioning equation predicts equilibrium solution concentrations based on existing concentrations of contaminants in soil. These concentrations may be reduced as a function of time, but this would require an e^{-kt} term to be applied to the entire equation, not a rate constant k added to the denominator.

- Comment #2. Dissolution-based guidance for cleanup. It is true that currently EPA does not have any guidance on dissolution-based models for calculating clean-up standards. But there are abundant literatures on chemical weathering of minerals that can be adopted to COPR and COPR-soil systems. Attached #1 is but one of the many current publications regarding chemical weathering process.*

Response: These are very general references, and they will not provide practical tools for use with COPR waste sites.

- Comment #3. Classification of COPR and COPR-Soil Materials. It was suggested to use pH and total Cr as the two indicators for differentiating pure COPR from COPR-soil mixture. Other indicators such as Ca to Si (Ca/Si) and /or Ca to Al (Ca/Al) molar ratio or Cr to Si (Cr/Si) and/or Cr to Al (Cr/Al) molar ratios may also give useful information.*

Regardless of what indicators to be used, one most important issue to be addressed is the threshold value, that is, what is the dividing line between a COPR and a COPR-soil matrix. One suggestion to deal with the above question is to compare the indicator values, e.e., pH or Ca/Al against results from surface characteristics, e.g., XRD, XPS, and NEXAF. A threshold value can be drawn along the line where there is clear indication the presence of specific mineral phases intrinsic to the pure COPRs.

Response: We agree. Research conducted toward separating COPR material from chromium contaminated soil should look into these possibilities. However, any techniques developed should be practical for routine use.

• *Comment #4. Chemical transformation of Cr. The geochemical cycle of chromium is complex. Many factors can affect the extent and the rate of the transformation of chromium, i.e., Cr(III)-Cr(VI). In the soil matrix, chemical species such as dissolved organic matter (e.g., soil humic substances), Mn, Fe, nitrogen (nitrate and ammonia) and sulfur are obvious ones. In the atmospheric side, chemical species such as oxygen, CO₂, SO_x and NO_x and ozone (from UV light reaction with water and atmospheric oxygen) call all participate at the geochemical transformation of chromium. Therefore, meteorological conditions may be as important as the soil chemical environment in the transformation of chromium.*

Response: We have addressed issues of atmospheric oxygen in the discussion of interconversion. We have not found any studies that look at effects of ozone, NO_x or SO_x on chromium transformations. However, sulfate, whether in rainwater or other media, can compete with chromate ion for adsorption sites. The only study we have found so far that examines the effects of temperature on Cr (VI) leaching is Weng et.al., 2002. We have added a phrase referencing the results of this study to the discussion of Cr (VI) leaching. We do not have adequate information at present to address the effects of other meteorological phenomena or to indicate their importance relative to the soil chemical environment.

• *Overall, this report is very well prepared and documented. The Workshop has more than adequate in addressing all charges from the NJDEP Commissioners. Recommendations to NJDEP are rightfully proposed. The reviewer wishes to recommend the approval of this report.*

No Response.

Attachment #1. Submitted by C.P. Huang

Chemical Weathering literature.

Volume 31, 1997 Mineralogical Society of America

CHEMICAL WEATHERING RATES OF SILICATE MINERALS

A.F. White & S.L. Brantley, Editors

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